

Mouser Capacitors in Nitrogen Temperatures and Operating Voltages

Kelly Swanson

1. Introduction

A large-scale Liquid Argon detector is being planned for construction, and with this project, as well as with other experiments involving cold temperatures, it is important that the electronics used do not break down or act in an unpredictable way.

Capacitors of different values were purchased from Mouser Electronics, and depending on whether they are damaged or changed by the conditions of the experiment, these capacitors may be suitable for the planned Liquid Argon detector.

Capacitors (see Figure 1):

- 10 nF, ceramic leaded COG/NPO, voltage rating: 500 V, P/N: 80-C333C103JCG5C (1)
- 10 nF ceramic SMD X7R, voltage rating: 200 V, P/N: 843-1206J2000103KX (2)
- 10 nF ceramic SMD X7R, voltage rating: 500 V, P/N: 843-1206J5000103KX (3)
- 10 nF ceramic SMD X7R, voltage rating: 630 V, P/N: 80-C1812C103KBR (4)
- 100 nF high voltage ceramic SMD X7R, voltage rating: 2500 V, P/N: 581-2225WC103K (5)

These capacitors were tested in liquid nitrogen and at operating voltages to ensure they work as desired. Liquid nitrogen was chosen for this test since it is more readily available than liquid argon as well as being colder (77K versus 87K).

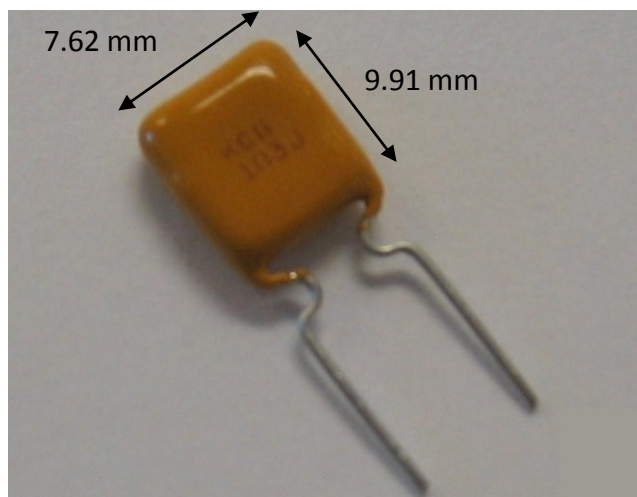


Figure 1a: 10 nF ceramic leaded capacitor

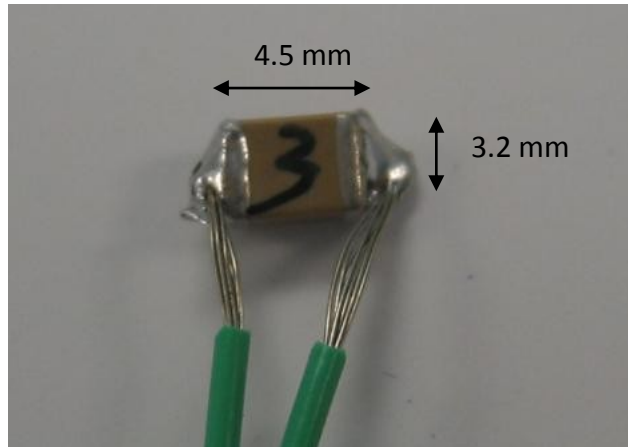


Figure 1b: 10 nF, 630 V X7R capacitor

2. Methods and Materials

i. Testing Capacitance

Before testing, wired leads were soldered to the ends of the capacitors to allow them to remain submerged in the liquid nitrogen and attached to the equipment (see Figure 2). The capacitances were measured both in room temperature and in liquid nitrogen using a Sencore Capacitor-Inductor Analyzer Model LC76 (see Figure 3). The room temperature results were a control from which it could be determined if the cold temperature had any adverse effects on the capacitors.

Each capacitor was connected to the Analyzer and placed in the nitrogen (see Figure 4). After waiting for the capacitor to reach the same temperature as the nitrogen—when the liquid around the capacitor stopped boiling—and while it was still submerged, its capacitance was measured. Once removed from the liquid, it was warmed back to room temperature and then placed back in the nitrogen where its capacitance was measured again. This was performed five times per capacitor to determine if it was affected by repeated temperature shocks.



Figure 2: Leaded capacitor with soldered wire leads.



Figure 3: Sencore Capacitor-Inductor Analyzer



Figure 4: Nitrogen pot with a capacitor submerged in the liquid

ii. Testing Voltage Leakage

A high voltage supply was used to put an appropriate voltage across the capacitors. If the capacitors were shorted or leaking under such conditions, the supply would register a current where there should be none.

Each capacitor was connected to the supply, and the voltage was slowly increased up to twice the stand-off voltage given by the manufacturer. After the desired voltage was reached, the current was measured with the high voltage supply. This process was performed again with the capacitors in liquid

nitrogen, wire leads soldered to the ends to allow the capacitors to be both connected to the supply and fully in the liquid.

3. Results

i. Capacitance Test

At both room temperature and in liquid nitrogen, the capacitances of the leaded capacitors remained constant with no undesirable effects caused by either the temperature changes or the cycles. This is shown in Table 1a. The X7R capacitances varied with temperature, decreasing roughly 60-70% in the nitrogen (see Table 1b).

Capacitor #1	Capacitance (nF)					
	Room Temperature	Nitrogen: Cycle 1	Nitrogen: Cycle 2	Nitrogen: Cycle 3	Nitrogen: Cycle 4	Nitrogen: Cycle 5
Sample 1	10.2	10.2	10.2	10.2	10.2	10.2
Sample 2	10.2	10.2	10.2	10.2	10.2	10.2
Sample 3	10.3	10.3	10.3	10.3	10.3	10.3
Sample 4	10.1	10.1	10.1	10.1	10.1	10.1
Sample 5	10.0	10.0	10.0	10.0	10.0	10.0

Table 1a: Leaded Capacitances at Room Temperature and in Liquid Nitrogen.

Capacitor #	Capacitance (nF)					
	Room Temperature	Nitrogen: Cycle 1	Nitrogen: Cycle 2	Nitrogen: Cycle 3	Nitrogen: Cycle 4	Nitrogen: Cycle 5
2	10.8	4.38	3.98	3.91	3.89	3.92
3	10.4	2.76	2.75	2.77	2.76	2.77
4	9.4	2.29	2.30	2.30	2.29	2.28
5	97	43.2	4.30	42.2	42.0	42.3

Table 1b: X7R Capacitances at Room Temperature and in Liquid Nitrogen.

ii. Voltage Test

The current was undetectable to the sensitivity of the voltage supply, 1 nA, measured at the appropriate voltage across the leaded and X7R capacitors. This result occurred in both room temperature and in liquid nitrogen (see Table 2).

Capacitor #1	Voltage (V)	Current at Room Temperature	Current in Liquid Nitrogen
Sample 1	1000	Undet.	Undet.
Sample 2	1000	Undet.	Undet.
Sample 3	1000	Undet.	Undet.
Sample 4	1000	Undet.	Undet.
Sample 5	1000	Undet.	Undet.

Table 2a: Current through the leaded Capacitors. Undet.=<1 nA

Capacitor #	Voltage (V)	Current at Room Temperature	Current in Liquid Nitrogen
2	5000	Undet.	Undet.
3	400	Undet.	Undet.
4	1000	Undet.	Undet.
5	1300	Undet.	Undet.

Table 2b: Current through the X7R Capacitors. Undet.=<1 nA

4. Conclusion

The 10 nF leaded capacitors can be used in temperatures of liquid nitrogen, reliably remaining at the same capacitance with no leaking. As such, they are suitable for a liquid argon detector without compromising their ability to maintain their desired function. The X7R capacitors can be used if the decreases in their capacitances are taken into account.